ANATOMY OF THE PROTON STRUCTURE FUNCTIONS IN κ-FACTORIZATION

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We present the first experiment-based parameterization of differential gluon structure function, which is called upon in many applications. We compare κ-factorization and DGLAP approaches and analyze properties of DGSF, with special emphasis on soft-to-hard/hard-to-soft diffusion.

It has become a common wisdom to present a DIS off a proton as if occurring off distinct partons (gluons in small-x domain) in a quantum mechanical probabilistic fashion (the familiar DGLAP approach), which involves the integral flux of gluons with transverse momenta less or equal to Q^2 $G(x,Q^2)$, whose parameterizations are available to the community. This collinear DGLAP approximation has been suspected for a long time to break in the small-x domain, where the amplitude clearly develops the non-DGLAP features. In this regime one should turn to the original, diagrammatically straightforward relation (the so-called κ-factorization approach):

$$\frac{d\sigma_{\gamma^{(*)}p}(x,Q^2)}{d\log x} = \int\limits_0^{\frac{Q^2}{4x}} \frac{d\boldsymbol{\kappa}^2}{\boldsymbol{\kappa}^2}\sigma_{\gamma^{(*)}p}(\boldsymbol{\kappa}^2)\mathcal{F}(x,\boldsymbol{\kappa}^2)\,; \quad \mathcal{F}(x,\boldsymbol{\kappa}^2) = \frac{\partial G(x,\boldsymbol{\kappa}^2)}{\partial \log \boldsymbol{\kappa}^2}$$

with $\mathcal{F}(x,\boldsymbol{\kappa}^2)$ being the Differential Gluon Structure Function (DGSF) — the object of the small-x evolution BFKL equation.

In this work we pursued three goals: (1) construct a practical parameterization of DGSF consistent with experimental data on F_{2p} both in soft and hard region; (2) compare physical observables in the DGLAP and κ-factorization approaches and quantify the above statement on restricted applicability of DGLAP approach; (3) investigate so constructed DGSF, with emphasis on soft-to-hard/hard-to-soft diffusion.

Constructing an Ansatz for DGSF, we followed a pragmatic strategy: for hard gluons we made as much use as possible of the existing parameterizations of $G(x,Q^2)$, which we interpolated into the soft region in compliance with color singlet constraints, and we added the purely non-perturbative soft component, which was interpolated into the hard domain. This Ansatz has several free parameters, which we adjusted by matching the DGSF-based description of

F_{2p} with experimental data throughout the whole Q^2 region ($\sigma_{\gamma p}$ in the $Q^2 = 0$ limit). The explicit form of parameterization as well as sets of parameters are given in [1]. Thus, we can state that we extracted DGSF from experiment and put it into the form of handy parameterizations, available to the community.

Upon constructing the explicit for of DGSF, we can compare the integrated gluon density $G_D = \int_0^{Q^2} \mathcal{F}(x, \boldsymbol{\kappa}^2) d\log \boldsymbol{\kappa}^2$ with the DGLAP output G_{pt}. This comparison reveals that though G_D and G_{pt} do converge at ultimately high Q^2, they differ significantly at moderate Q^2, divergence being more prominent at smaller x. At $x = 10^{-5}$, G_{pt} is two-three times higher than G_D for Q^2 up to 100 GeV^2. This should be regarded as a warning against unwarranted applications of DGLAP-based quantities in the small-x domain.

One of the principal features of the κ-factorization approach is the soft-to-hard and hard-to-soft diffusion phenomenon, which originates from lifting of strong ordering of transverse momenta, inherent to DGLAP. The explicit subdivision of our DGSF Ansatz into soft and hard parts makes it possible to track down effects of soft gluons in the hard region and vice versa. We observed that the soft, non-perturbative component does not vanish and even rises with Q^2 in F_{2p}, being a dominant feature of F_{2p} for $Q^2 \leq 10$ GeV^2 at $x = 0.8 \cdot 10^{-3}$.

The reverse side of the same phenomenon, the hard-to-soft diffusion, stands behind the energy rise of the real photoabsorption cross section. We emphasize that the correct energy rise was modelled in the approach with manifestly energy independent soft component: the rise is entirely due to hard-to-soft diffusion (contrary to the Donnachie-Landshoff type parameterizations of color dipole cross sections, where the soft intercept is the input quantity).

Another finding came from small-x growth of different observables (and their hard parts), which we presented in terms of effective intercepts. We observed transition from a strongly Q^2-dependent hard intercept in the case of $\mathcal{F}(x, \boldsymbol{\kappa}^2)$ to almost Q^2-independent intercept of the integral quantity F_{2p}. From the Regge theory point of view, this dramatic flattening leads to a very simple two-pole picture of F_{2p}: almost fixed pole with $\Delta_{hard} \approx 0.4$ hard part plus energy independent soft constribution.

References

1. I.P. Ivanov, N.N. Nikolaev, E-print: hep-ph/0004206 (2000).